First Results From the GeoSAR Mapping Instrument

by

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GeoSAR Program

- GeoSAR is a consortium project consisting of JPL, Calgis (a small GIS company based in Fresno, CA) and the California Department of Conservation with funding provided by DARPA started in November 1996.
- The two main objectives of the GeoSAR Program are
  - to develop a state of the art dual frequency interferometric radar mapping instrument capable of mapping the true ground surface height beneath the vegetation canopy.
  - to transition this mapping technology to a commercial company, Calgis.
- JPL, the technical lead, has the following program deliverables at program completion in November 1999 include
  - radar design and radar hardware for X-band (3 cm) and P-band (83 cm) radars
  - processor software, hardware and documentation
  - calibrated X-band radar

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Mapping System

- Mapping System Will Consist of:
  - Aircraft platform to host data collection hardware (Gulfstream II)
  - Flight planning software
  - Dual frequency (X-band/UHF) interferometric SARs
    - Single polarization @ X-band
    - Dual polarization @ UHF
    - Automated radar control
  - Laser interferometric baseline measurement system augmented with embedded GPS/INU systems and differential GPS for precision reconstruction of aircraft flight trajectory and attitude history
  - SAR processors capable of producing DEMs @ X-band and UHF and a true ground surface DEM from combined X-band/UHF analysis
  - A GIS system to analyze digital data

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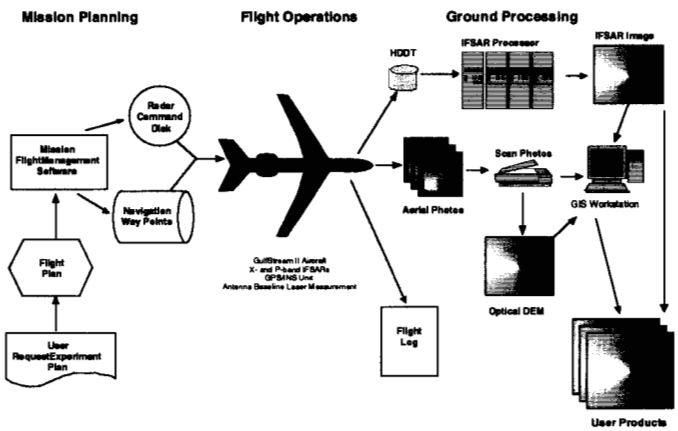
GeoSAR End-to-End System

GeoSAR



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Mapping System Requirements

1. **Dual Frequency:** UHF and X-Band Interferometric Radars
2. **Polarization:** HH, HV (or VV, VH) at UHF; VV at X-BAND
3. **Height Accuracy: (1 Sigma, Averaged Over Swath)**
   - UHF:
     - 30% Of Tree Height RSS With 4 m @ 10 km Altitude (Absolute)
     - 33% Of Tree Height RSS With 2 m @ 5 km Altitude (Absolute)
   - X-Band:
     - 1 m @ 10 Km Altitude, 0.7 m @ 5 km Altitude (Relative)
     - 2.5 m @ 10 Km Altitude, 1.8 m @ 5 km Altitude (Absolute)
4. **Planimetric Accuracy: (1 Sigma)**
   - UHF
     - 4 m @ 10 km Altitude; 0.7 m @ 5 km Altitude (Relative)
   - X-Band
     - 1 m @ 10 km Altitude; 0.7 m @ 5 km Altitude (Relative)
     - 2.5 m @ 10 km Altitude; 0.8 m @ 5 km Altitude (Absolute)
5. **Posting:** Variable, but Nominally 5 m
6. **Flight Range:** 2,500 Nautical Miles Minimum

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Mapping System Requirements (Cont)

7. **Data Collection Duration:** 2 Hours at Altitude; 1 Hour for Ascent and Descent
8. **Aircraft Operating Altitude:** Up to 13 km
9. **Aircraft Air Speed:** Up to 380 Knots
10. **Radiometric Calibration:**
    - 6 dB Absolute
    - 3 dB Relative
11. **GPS/INU Unit:**
    - **3-Dimensional GPS Position Accuracy:** 10 cm
    - **3- Axis Angle Accuracy**: 15 arc-sec
    - **Clock Accuracy:** 1 Millisecond
    - **Data Sampling Rate:** Every 0.5 seconds
12. **Swath Size:** Minimum 10 km @ 10 km Altitude
13. **Radar Data Collection Rate:** Minimum of 115 Sq km/minute

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Processor Elements

- GeoSAR processor unique elements
  - SAR processors capable of producing DEMs @ X-band and UHF and a true ground surface DEM from combined X-band/UHF analysis
  - Unique focusing and height reconstruction algorithms for P-band
  - Radio Frequency Interference software to remove unwanted interference from radio sources transmitting within the P-band bandwidth
  - True ground surface algorithms using a combination of X-band and P-band data
- Processor Status
  - Interface and performance testing with data recorded on the ground is going very well.
  - Able to generate height maps with TOPSAR data.
  - Algorithm development for true ground surface mapping continues with this still the major technical risk for the program.

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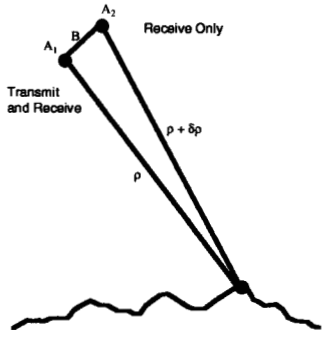
Hardware Elements

- Unique elements of GeoSAR radar hardware
  - Dual frequency (X-band/UHF) interferometric SARs
    - Single polarization @ X-band
    - Dual polarization @ UHF
    - Automated radar control
  - Laser interferometric baseline measurement system augmented with embedded GPS/INU systems and differential GPS for precision reconstruction of aircraft flight trajectory and attitude history.
- Hardware Status
  - completed fabrication of all hardware elements with exception of the Laser Baseline Metrology System (LBMS). Radar installed on aircraft at Van Nuys Airport.
  - Being flight test for FAA certification.

JPL System Performance Analysis Overview

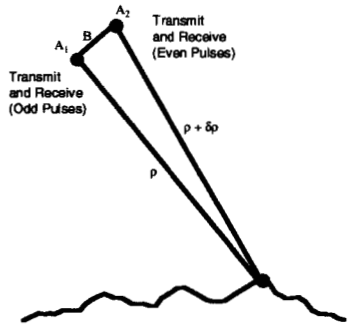
Single vs Double Baseline Operation

GeoSAR



$$\phi = \frac{2\pi}{\lambda}(\rho + \delta\rho - \rho) = \frac{2\pi}{\lambda}\delta\rho$$

Single Baseline
(Non Ping-Pong)



$$\phi = \frac{2\pi}{\lambda}(2\rho + 2\delta\rho - 2\rho) = \frac{4\pi}{\lambda}\delta\rho$$

Double Baseline
(Ping-Pong)

JPL System Performance Analysis Overview

GeoSAR

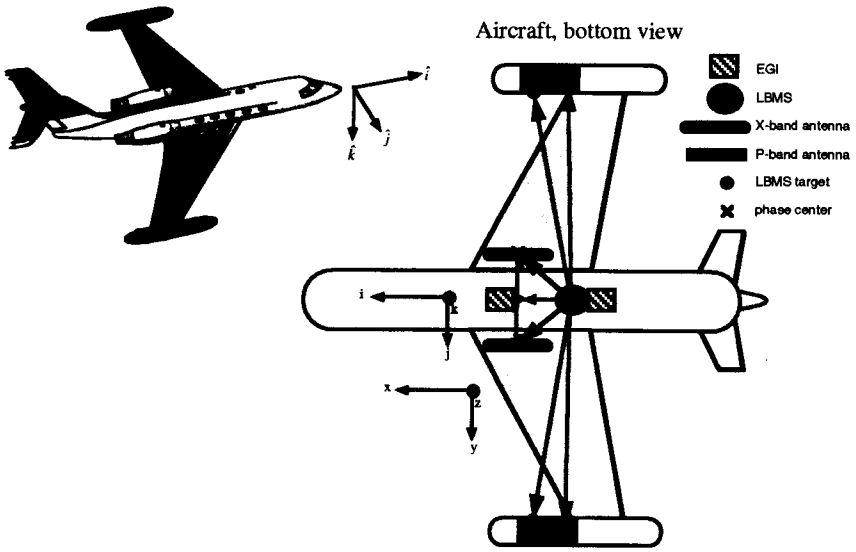
UHF SYSTEM PARAMETERS

Parameter	Value
Peak Transmit Power	4 KW
Bandwidth	80/160 Mhz
Pulse Length	40 μsec
Sampling	8/4 BFPQ @ 160 MHz 8 bit for 80 MHz
Antenna Size	1.524 m x 0.381 m
Antenna Gain at Boresight	11 dBi
Antenna Look Angle	27 - 60 Deg
Antenna Boresight	60 Deg
Wavelength @ Center Frequency	0.86 m for 160 MHz 0.97 m for 80 MHz
Baseline Length	20 m /40 m
Baseline Tilt Angle	0 Deg
Platform Altitude	5000 m - 10000 m

X-BAND SYSTEM PARAMETERS

Parameter	Value
Peak Transmit Power	8 KW
Bandwidth	80/160 Mhz
Pulse Length	40 μsec
Sampling	8/4 BFPQ @ 160 MHz 8 bit for 80 MHz
Antenna Size	1.5 m x 0.035 m
Antenna Gain at Boresight	26.5 dBi
Antenna Look Angle	27 - 60 Deg
Antenna Boresight	60 Deg
Wavelength @ Center Frequency	0.031 m for 160 MHz 0.031 m for 80 MHz
Baseline Length	2.5 m /5m or 1.3m/2.6m
Baseline Tilt Angle	0 Deg or 45 Deg
Platform Altitude	5000 m - 10000 m

Aircraft System Illustration



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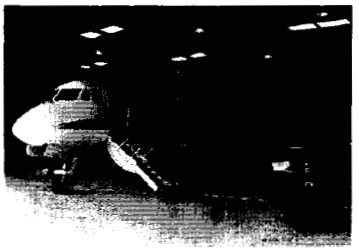
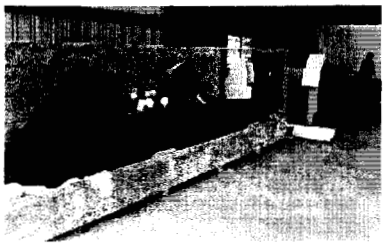
Hardware Development



GeoSAR platform is a Gulfstream II currently based in Van Nuys, CA.



One of two wing pods which will house the P-band antennas.

Internal view showing some of the 10 racks which comprise the GeoSAR radar.

Rack Installation

Radar Operator Workstation

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View of GeoSAR Aircraft Prior To Flight Test

- Plane is being modified by TAS at the Van Nuys Airport in California.

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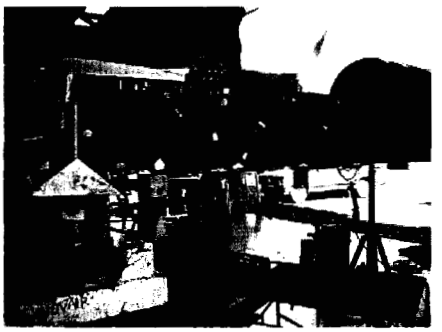
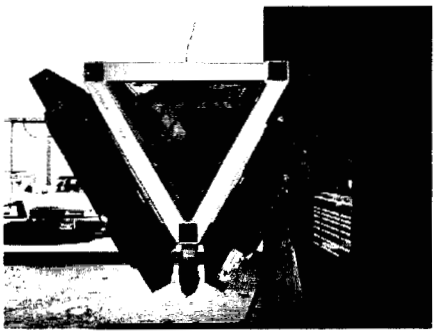
P-band Antennas





- P-band antennas are cavity fed microstrip arrays consisting of four radiating elements. Antennas are designed to operate with 160 MHz of bandwidth at a center frequency of 350 MHz.

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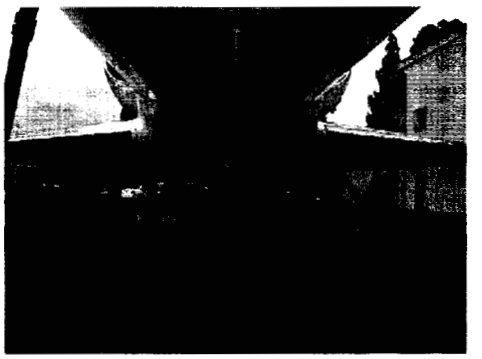
X-band Antenna Fairings

- X-band antenna are mounted underneath the fuselage and have a 160 MHz bandwidth at a center frequency of 9.2 GHz.



- Front view of the LBMS fairing and X-band antenna fairings.

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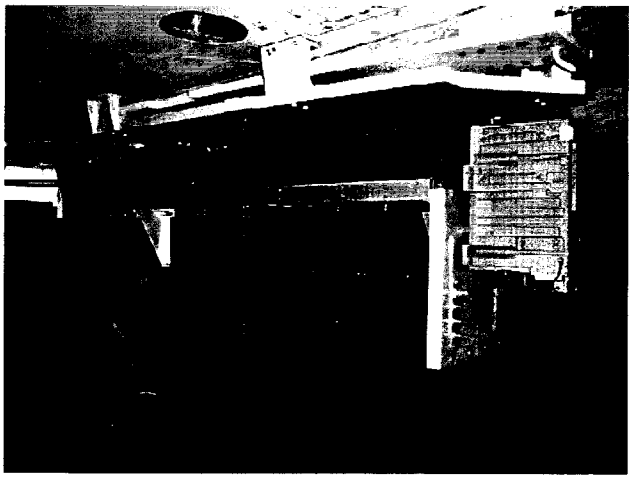
LBMS Spline and EGI



- LBMS spline which houses the LBMS elctronics and cameras. One of the EGI INU units is attached to the front of the LBMS spline.

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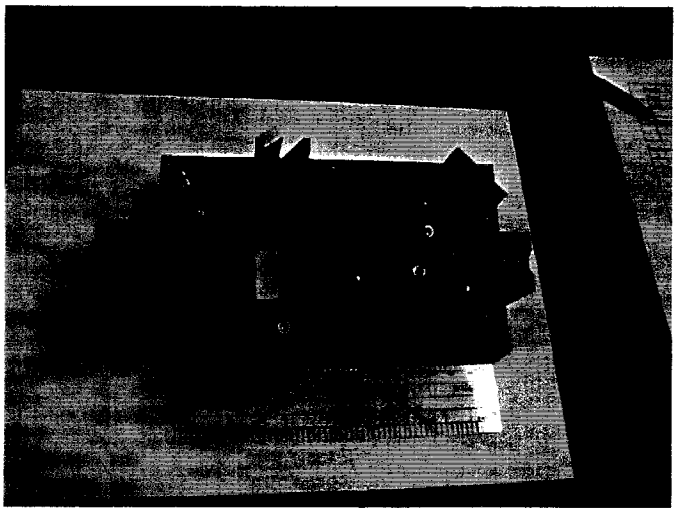
LBMS Camera



- One of the LBMS camera used to determine the P-band orientation and translation.

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GeoSAR Interior View

- The GeoSAR radar consists of 10 racks. Radar is operated from the Radar operator workstation. Data collection is fully automated.

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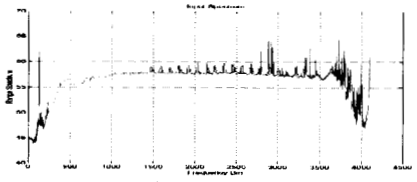
Sample Inputs

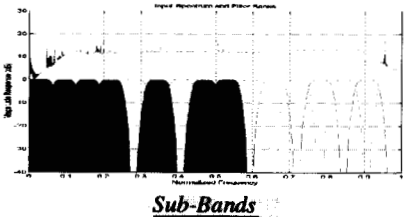
Flat Area

Hilly Area

Range-Doppler Images



One Band



Sub-Bands

Range Spectra

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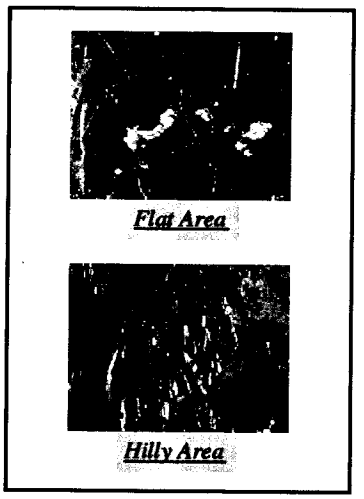
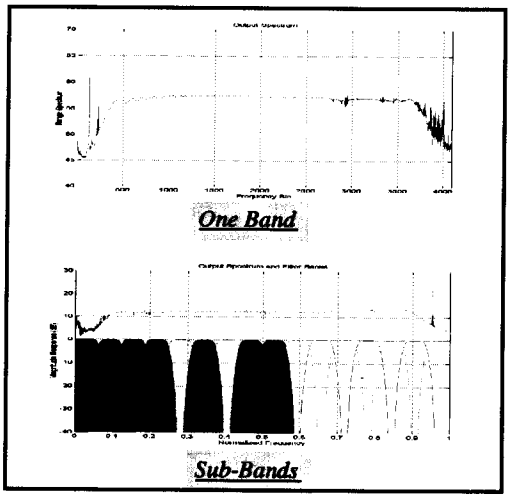
Sample Outputs



Range-Doppler Images



Range Spectra

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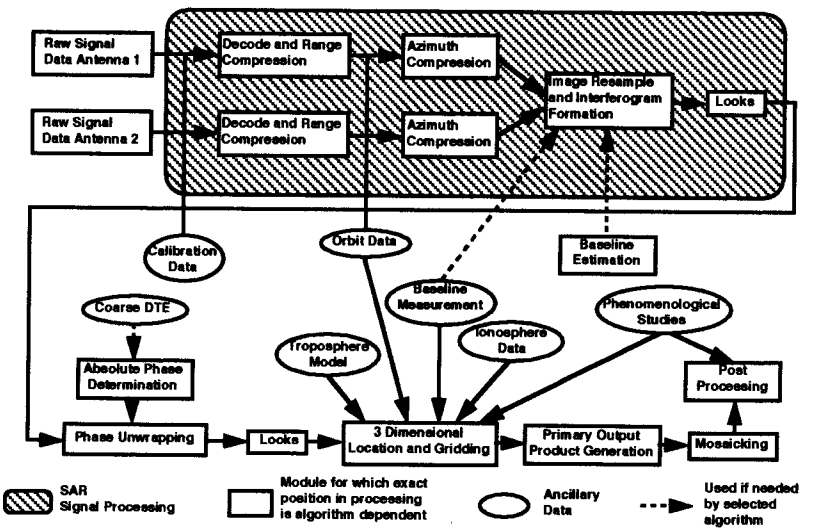
Interferometric SAR Processing Flow

GeoSAR



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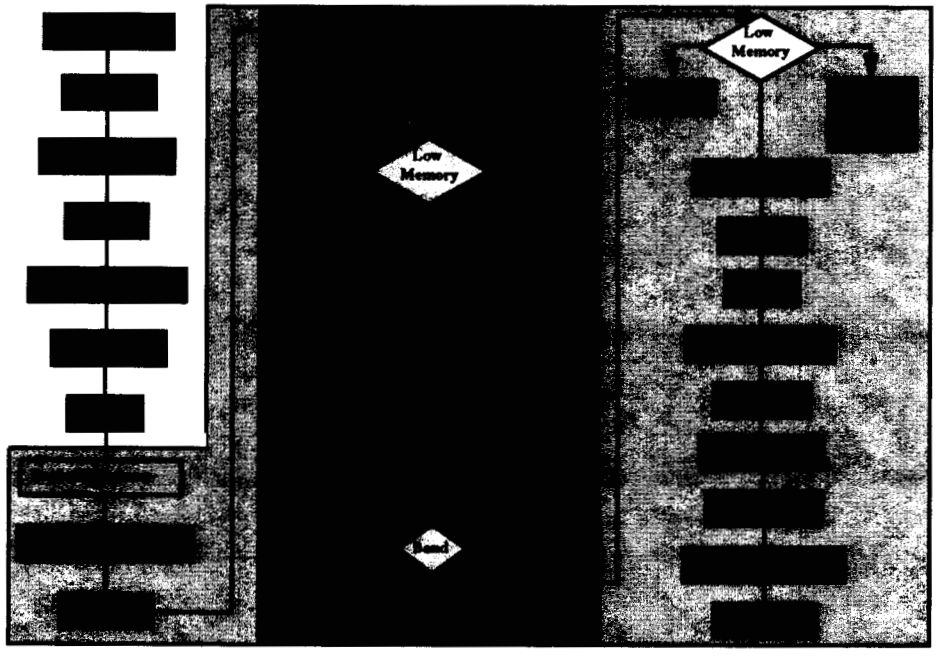
Jurassicprok Flow Diagram



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Height Maps - Before and After RFI Removal
Innisfail L-Band Ping-Pong Data

Before RFI (Tone Generators) Removal

After RFI (Tone Generators) Removal